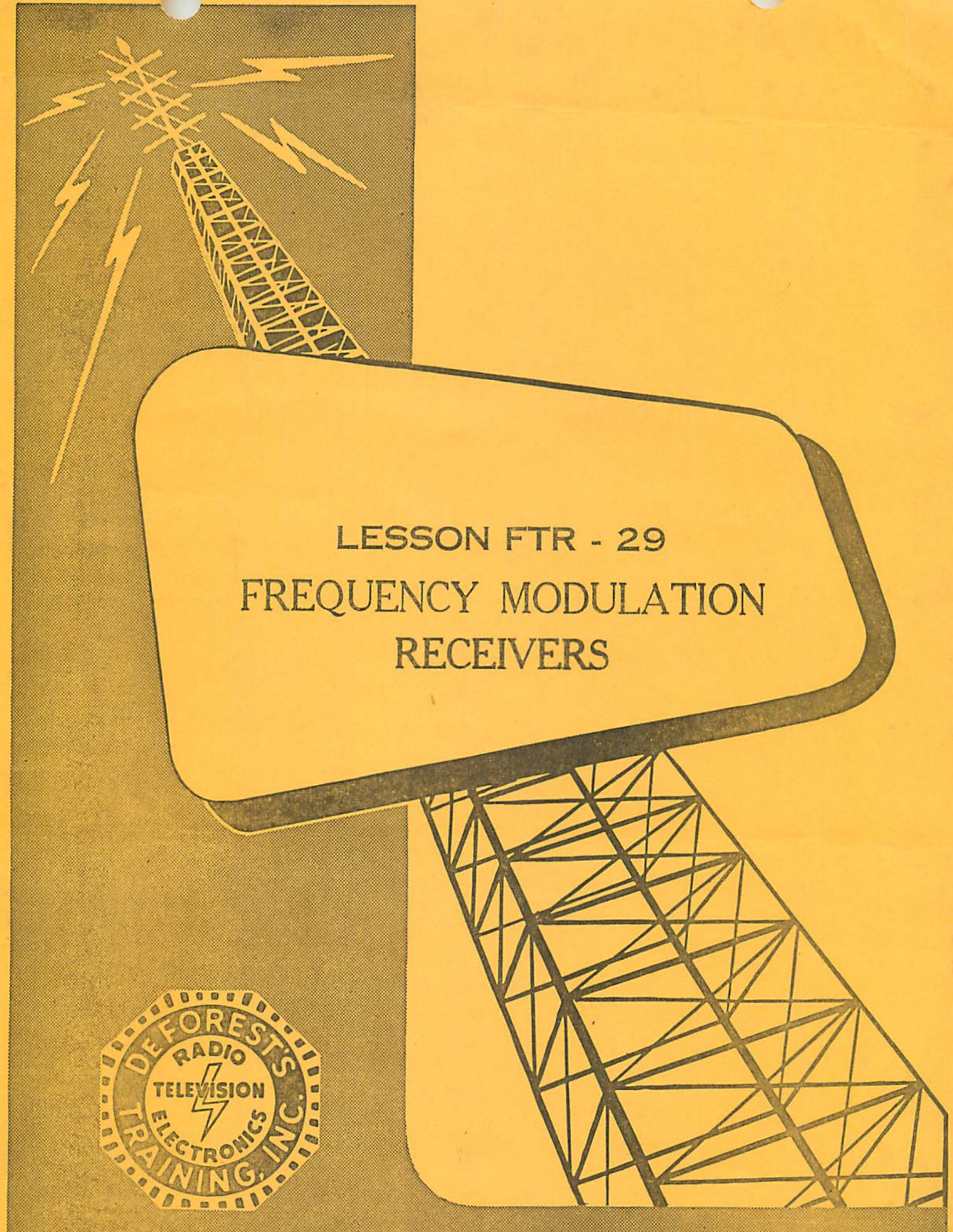

LESSON FTR - 29

FREQUENCY MODULATION RECEIVERS

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LESSON FTR-29

FREQUENCY MODULATION RECEIVERS

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Luck is usually with a man who doesn't count on it.

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Taking things easy ultimately makes life hard.

......

The largest room in the world is the room
for self-improvement.

-- Selected

In our explanation of Frequency Modulation as a method of Radio Transmission, we made frequent comparisons to the common Amplitude Modulation methods in order to bring out both the similarities and differences of the two systems. For this Lesson, we will follow the same plan in respect to Receivers because, while there are many similarities, the few differences are extremely important.

You may find it necessary to completely revise a few of your present ideas, in respect to the reception of Radio signals, because in some ways, the action of the two systems are in almost direct contradiction. Keeping this fact in mind, may make it easier to understand some of the following explanations.

Later in this Lesson we will show you that, in general, the input stage, mixer, i-f amplifier and audio amplifier are about the same for superheterodyne receivers of either the a-m or f-m type. The main difference occurs at the output of the i-f amplifier and, therefore, that is where we want to start.

RECEPTION OF A-M SIGNALS

As a brief review, the curve of Figure 1-A represents an a-m carrier which we will consider as the output of an i-f amplifier or as the voltage which is impressed on the input circuit of the second detector.

Thinking of a diode detector, which acts as a rectifier, with an input as shown by curve A, the output will be as indicated by curve B of Figure 1. Notice here, we still have the carrier frequency but, instead of complete cycles, it has become a series of pulses, all of which are above the a-c axis and therefore, commonly considered as pulsating d-c.

By placing a small capacity across the output circuit, the peaks of these pulses will cause it to charge, in proportion to their amplitude while, between peaks, the condenser will discharge. As a result, the current in the circuit will be about the average of the peak amplitudes and, for the curve of B, will have the general shape of the curve C, Figure 1. Notice the resultant signal wave has a reference axis shown by the horizontal line.

Thus, we say the carrier, shown at A, has been demodulated and the modulating Frequency, shown at C, is carried over to the audio frequency circuits where it is amplified to the desired level.

SOURCES OF INTERFERENCE

In comparison to the curve of Figure 1A, for Figure 2, we have a curve which represents the output voltage of an f-m intermediate frequency amplifier. Notice here, the curve shows both frequency and amplitude modulation and we want you to think of the signal as Frequency Modulation while the changes of amplitude represent interference or noise.

As a radio listener, you are probably familiar with various things which tend to spoil the reception of radio signals. However, we want to list a number of interfering sources without offering detail concerning their characteristics.

In general, the principal disturbances to a-m reception can be classified as follows: (1) Man-made interferences, which occur when there are irregular radiations from such sources as electrical power equipment and auto ignition systems. (2) Static arising from electrical discharges in the atmosphere. (3) Thermal agitation noise, which is generally caused by small potentials set up in the conductors of the first stages of a receiver by random motions of electrons. (4) Interference resulting from the reception of signals from stations other than the desired station. (5) Tube noise, caused by random fluctuations in the rate at which electrons reach the plates of vacuum tubes. (6) Hum modulation of the signal, which can take place in an a-c receiver where a-c is used to heat the cathodes of the tubes, and when the d-c power supply is not adequately filtered.

It is a well established fact that the greater part of the unwanted noise which accompanies a radio signal is due to changes of amplitude in the carrier. Thus, for the a-m systems, in which the desired signal also causes changes of carrier amplitude, it is difficult to reduce the noise without causing a similar effect on the signal. ①

For the f-m carrier of Figure 2, however, the signal modulation causes changes of frequency while the noise causes changes of amplitude. Therefore, if the changes of amplitude can be eliminated, the noise will be removed without affecting the signal. This particular condition is one of the important advantages of frequency modulation. ①

LIMITER

To eliminate the changes of amplitude a "Limiter" stage, with a circuit on the order of Figure 3, is employed. The tube is a pentode of the sharp cut-off type with its cathode grounded, and as far as the power supply is concerned, the tube operates a zero grid bias. ②

However, the grid circuit is connected across the tuned secondary of the last i-f transformer so that the curve of Figure 2 represents the signal voltage at this point. The resistance R, by-passed by condenser "C", is placed in series with the complete grid circuit.

The positive alternations of the Carrier will cause the grid to become positive, in respect to the cathode and, therefore, during these periods, there will be current in the grid circuit. Passing through resistance R, this current will produce a voltage drop the polarity of which tends to make the grid more negative. Also, the voltage across R will charge condenser C, and this d-c voltage will be very nearly equal to the amplitude of the i-f voltage across the tuned circuit condenser.

During the negative alternations of the carrier, the grid will be negative, in respect to the cathode, and there will be no grid current. Under this condition, the reduced voltage drop across R will allow condenser C to discharge through it and thus momentarily maintain the voltage. As the polarity of the voltage drop does not change, in effect there is a d-c bias on the grid.

You can readily see that the greater the amplitude of the carrier, the greater the positive voltage on the grid and thus the greater the grid current. This greater current will cause a larger drop across R and charge the condenser to a higher voltage. Thus, the grid bias will vary with the carrier amplitude much the same as in the common avc systems and, in some f-m receivers, the voltage across R is used to provide Automatic Volume Control.

To provide the limiting action, the tube is operated at comparatively low plate and screen voltages and, during the positive alternations of the carrier, the positive grid voltage causes the plate current to quickly reach a point of saturation. During the negative alternations of the carrier, the signal voltage plus that across R, quickly reaches a value which causes plate current cut-off.

The time constant "RC" is important in the suppression of impulse noises, such as ignition radiation and sparking brushes of electric motors. In general, the time constant should not exceed 10 microseconds, and more conventional values range from 1.25 to 4 microseconds.

Short time constants make it possible for the grid bias voltage, developed across R, to follow almost instantaneously an impulse which would remove the signal voltage from the grid of the limiter tube. The short time constant permits recovery of the bias voltage in less than the time of one cycle at the highest audio frequency used, and the bias system then does not prolong the effect of an individual interferring pulse.

Thus, with properly chosen values in the limiter stage, the lowest carrier amplitude will cause saturation and greater amplitudes of carrier can not cause greater changes of plate current. Therefore, with the voltage of Figure 2 applied on the grid circuit of Figure 3, the plate circuit will carry all the changes of frequency but, due to the limiting action, the amplitude will be constant.

To realize the full advantage of this noise reducing feature, the signal reaching the limiter grid must be of such strength that the minimum amplitudes will produce limiter saturation. Then, any increase of carrier amplitude will not cause an increase of the limiter output.

In some respects, the circuit of Figure 3 resembles a grid leak type of detector which has the bad fault of cutting off high amplitude signal peaks and causing distortion. Here, such tube action is an advantage as we want to cut-off the variations of amplitude in order to eliminate the noise which accompanies the signal.

From the standpoint of the reduction of noise and interference, the limiter stage is the most important component of the f-m receiver, because f-m detectors respond to amplitude as well as frequency variations of the detector input voltage.

Although we show a single stage limiter in Figure 3, some f-m receivers employ 2 stages, the second for the purpose of removing any small amplitude variations in the output of the first limiter, and to flatten the over-all characteristic curve after the point of tube saturation is reached.

I-F AMPLIFIERS

In amplitude modulation receivers, the i-f transformers are usually peaked to pass a band of approximately 10 kc. The narrower this band is made, the greater the selectivity of the receiver but, for good reproduction, the band must be twice as great as the highest signal frequency it is desired to reproduce. Theoretically at least, a 10 kc pass band i-f can handle signal frequencies only up to 5 kc or 5000 cycles.

For f-m systems, the pass band of the i-f amplifier has nothing to do with the signal frequencies as they merely control the rate at which the carrier frequency changes. However, as we have previously explained, the relative value of the signal is in proportion to the change of carrier frequency.

Therefore, by increasing the band width, the relative strength of the signal is increased and the signal to noise ratio is improved. Or, saying it the other way, the greater the frequency deviation the better the noise suppression.

As already mentioned, for present f-m Broadcast practice, the ratio of Frequency Deviation to Maximum signal Frequency is about 5 to 1. As 15,000 cycles is considered necessary for good fidelity, the deviation is 5 times 15,000 cycles or 75,000 cycles which is equal to 75 kc. Then, as deviation means the frequency change on one side of the carrier, the total swing, equal to twice the deviation, is 2 x 75 = 150 kc.

Because of this condition, the Federal Communications Commission have allocated 200 kc bands for the f-m transmitters now in operation and most i-f amplifiers are considered as having this value of pass band.

3½

The intermediate frequency of early receivers had a value of 2.1 mc which has been increased through values of 4.3 mc, and the post war trend is toward the use of still higher intermediate frequencies. The use of the "odd Tenths" in the value of the i-f's is for the purpose of minimizing the image frequency. It is desirable that such interference lie outside the f-m band.

The transformers are of the usual type with a tuned primary and secondary and, to provide the required band pass, the coils are tightly coupled and usually loaded by a resistance connected across them which acts to broaden the response characteristics. Depending on the design and requirements, the broading resistors vary from about 10,000 to 100,000 ohms.

In other receivers, the characteristic response of the i-f amplifier does not differ greatly from that of an a-m type of receiver, the flat top response being obtained by the action of the limiter.

To illustrate, for Figure 4, we have drawn three curves, representing the relative response of an i-f amplifier at different carrier levels. You can imagine these various levels as being obtained by increasing either the signal strength at the antenna or the gain of the amplifier itself.

The vertical scale at the left indicates the relative voltage of the output measured at different frequencies as marked along the bottom, horizontal scale. Checking this scale, you can see the amplifier is tuned to 2100 kc or 2.1 mc, because the output is maximum at that frequency.

Starting with curve "A", the output at 2100 kc is approximately 4, on the voltage scale, but, as the frequency is varied above and below resonance, the voltage drops quite rapidly.

For curve "B", the resonant voltage is 50% greater than that of curve A but as the amplifier circuits have not been changed, both curves have the same general shape.

For curve "C", with a still higher resonant voltage, the general shape remains the same as shown by "A" and "B" but the curve is higher and broader.

From our explanation of the limiter, you know it is arranged to have a comparatively low saturation point which we have indicated as "3" on the voltage scale of Figure 4. Thus the complete curves represent the voltage on the limiter input circuit while the lower, heavier portions, represent the limiter output.

Checking across the "3" line, you will find curve "A" is "flat-topped" for 25 kc each side of the resonant frequency and thus the limiter action would be effective for a frequency swing of 50 kc.

Curve "B" is flat topped for 50 kc each side of resonance and, with an input voltage of this amplitude, the limiter action would be effective for a frequency swing of 100 kc. Curve "C", flat-topped for 75 kc each side of resonance, would provide limiter action for the 150 kc swing of present broadcast practice.

From these curves, you can readily see that it is desirable to provide a relatively strong signal at the input of the limiter in order that the minimum amplitude be sufficient to operate it.

The main purpose of the Limiter is to remove the amplitude modulation from the carrier and thus remove the noise, static or other interference without affecting the signal. Remember however, some interference is frequency modulated and therefore, even though the limiter is operating properly, some noise may be heard in the speaker. 2

Assuming perfect Limiter action, its output will have a constant amplitude and the modulation will appear only as a variation of frequency.

DISCRIMINATOR

To produce audible signals of the desired volume, the usual types of audio amplifiers and speakers are employed and therefore, the frequency changes of the limiter output must be converted into corresponding changes of voltage or amplitude.

The circuit arrangement, used for this purpose, is similar to the "Discriminator" which was developed as a part of the Automatic Frequency Control (afc) systems found in some superheterodyne Radio Receivers, and it would be well to review the explanations should you have forgotten some of them.

A simplified circuit of this stage is shown in Figure 5 and you can imagine tube T1 is the Limiter of Figure 3, with the tuned primary, L1-C1 of the i-f transformer, in its plate circuit.

The tuned secondary, L2-C2, is center tapped and connected to the double diode, T2, in a full wave rectifier arrangement. Two resistors of equal value, R3 and R4, each bypassed with a condenser, are connected in series across the cathodes to form the output load.

Notice also, that while the lower end of R4 is grounded, the center tap between R3 and R4 connects to the center tap of L2 through the "R.F.C." which is a radio frequency choke. In addition, the center tap of L2 is coupled to the plate of T1 through condenser C.

With this arrangement, the total voltage, applied across the load resistors R3 and R4 can be thought of as consisting of two separate parts. To follow these paths, you must remember we are considering the comparatively high intermediate frequency value and thus a condenser acts as a capacity reactance allowing us to trace an a-c path through it.

Under these conditions, we can start at the plate end of L1-C1 and follow a path through coupling condenser C and through the Radio Frequency choke, (R.F.C.) to the junction between R3 and R4. From this point, there are two paths to ground, one through R4 and one through C4.

At the comparatively high intermediate frequency, the reactance of the condenser is so low, compared to the resistance, that it shorts it out and the path is through C4 to ground and back through C6 to the lower end of L1-C1.

The voltage across L2-C2 rectified by tube T2, has two d-c paths, one from the upper cathode through R3 and RFC to the center tap of L2 and the other from the lower cathode through R4 and R.F.C. to the center tap of L2.

Checking back, you will find that the paths we have traced across L2-C2 are such that the voltages will cause current in one direction through R3 and in the opposite direction through R4. Thus, any voltage drop developed across these resistances will be of opposite polarity and tend to reduce the total voltage across both of them in series.

Going back to the i-f transformer, the desired action depends upon a number of phase relations which we want to explain with the aid of the vectors of Figure 6.

6/10

In any inductance, such as L1, the current lags the voltage by an angle which we can assume to be 90°. To represent this condition, in Figure 6A the vertical vector "Ep" represents the voltage and the horizontal vector "Ip", the current. The comparative lengths of these vectors have been chosen arbitrarily as we are interested mainly in phase angles rather than actual values.

The current in L1 will induce a counter emf but, as the greatest induction occurs when the current is changing value at the greatest speed, which is at zero value, the induced emf will lag the current by 90°. This value is represented by the vector, "Ec", and you will find it is 180° out of phase with the impressed voltage Ep. Remember, the flux which induces the primary counter emf also cuts the secondary and thus Ec represents the induced emf in the secondary.

When the secondary circuit, L2-C2, is tuned to resonance, its reactance is zero and thus its current will be in phase with the induced voltage "Ec" as shown by vector "Is". However, L2 is an inductance and therefore, as explained for L1, the voltage across the coil will lead the current in the coil by 90°.

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To illustrate this action, we have drawn vector "E1" of Figure 6A 90° ahead of Is which brings it in phase with Ip. However, in the circuit of Figure 5, L2 is center tapped and each end is connected to a rectifier plate with the center tap as a common return.

In respect to this common return, the voltage E2 across one half of the winding will be of opposite polarity or 180° out of phase with the voltage E1, across the other half of the winding. For this reason, vectors E1 and E2 of Figure 6A are drawn of equal length but extended in opposite directions from the vector Is.

Going back to Figure 5, you will remember that the RFC was in the path of the voltage developed across L1-C1. Current in this path will therefore, develop a drop across the choke and this voltage can be considered the same as that across L1-C1, the vector for which is shown as "Ep" in Figure 6A.

With this in mind, you will find the voltage "Ep" is in series with voltages E1 and E2, the circuits for which are completed through the rectifier and resistances R3 and R4. Thus, the total voltage across R3 will be proportional to the sum of Ep and E1 while the voltage across R4 will be proportional to the sum of Ep and E2.

Adding these vectors by the usual plan of completing the parallelogram and drawing the diagonal, we have vector ER3 as representing the voltage across R3 and ER4 as representing the voltage across R4.

Notice here, the current in the resistances is the result of rectification by T2 and, with a condenser across each of them, we can consider the voltage drop as d-c. Because of the direction of current, the upper end of R3 and the lower end of R4, Figure 5, will both be positive, in respect to the center tap. This will cause an opposing action and the total voltage across both of them will be equal to their arithmetical difference or algebraic sum.

We need consider only the length or value of vectors, ER3 and ER4 of Figure 6A and, as the diagram is symmetrical, both have the same length. Therefore, as the voltages acress R3 and R4 are of equal value and opposite polarity, the total voltage, across both of them, is zero.

In the complete f-m receiver, the vectors of Figure 6A represent the condition at the exact intermediate frequency which is present when there is no modulation and the carrier frequency has its mean or center value.

Suppose now, the carrier frequency changes and causes a deviation from the i-f value. As far as the diagrams of Figure 6 are concerned, this will not cause any change in the phase relations of "Ep", "Ip" or "Ec". At a higher frequency, however, the capacity reactance of C2 will reduce while the inductive reactance of L2 will increase.

This increase of inductive reactance will cause the secondary current "Is" to lag the voltage "Ec" as shown in Figure 6B. As explained for Figure 6A, the induced voltages, E1 and E2 are 90° out of phase with Is and, therefore, are drawn at this angle in Figure 6B.

Completing the parallelogram and drawing in the diagonals under these conditions, we see that vector ER4 is longer than vector ER3 and, therefore, know the voltage across R4 is greater than that across R3.

The total voltage, across the resistors in series, will be equal to their difference and have the polarity of the larger voltage drop. Thus, as R4 is positive at the grounded end, the upper end of R3 will be negative in respect to ground. The greater the change of frequency, the greater the difference between the respective voltage drops and thus, the value of the negative voltage, between the upper end of R3 and ground, Figure 5, will increase with the increase of frequency above the resonant frequency of L2-C2.

When the intermediate frequency drops below the resonant value, the capacity reactance of C2 increases and the inductive reactance of L2 decreases. As a result, the tuned circuit becomes capacitive and the secondary current "Is" leads the induced voltage "Ec" as shown in Figure 6C.

Following the former plans, vectors E1 and E2 are again drawn at 90° angles to Is, the parallelograms completed and the diagonals, ER3 and ER4 drawn in.

Here, you can see that conditions are opposite to those of Figure 6B and ER3 is longer than ER4. Going back to Figure 5, this means that the voltage across R3 is greater than that across R4 and therefore, the upper end of R3 will be positive in respect to ground.

To check the entire action, we could connect a sensitive voltmeter from the upper end of R3 to ground and then take readings as the frequency was varied above and below the value to which the i-f transformer was tuned.

The results of such a test, when plotted in the form of a graph, produce a curve on the order of Figure 7 where we have a frequency scale across the bottom and a center zero voltage scale at the left.

The intermediate frequency is assumed to be 2100 kc and, as already explained, the total voltage is zero at this point. As the frequency is reduced, the voltage rises in "+" value and, as the frequency is increased, the voltage increases in a negative direction. Thus, variations of frequency are converted to changes of amplitude and the output of the discriminator can be considered the same as the output of the second detector of an a-m superheterodyne receiver.

Looking at Figure 7 again, you will notice the curve is almost a straight line for a distance on each side of the resonant frequency, after which it starts to curve and then falls back toward zero.

The straight line section, as shown by the vertical broken lines, is the valuable range of the action because, between these limits the output voltage will vary in direct proportion to the frequency changes. As drawn in Figure 7, the frequency deviation is 75 kc for a swing or band width of 150 kc.

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In Figure 5, the voltage of Figure 7 is impressed on the network, made up of R1, C5 and the volume control R2 while the grid circuit of the following tube is connected across the "Output" terminals. The stages following the discriminator are those of the ordinary type of audio amplifier.

COMPLETE RECEIVER

To show how the various stages are inter-connected, for Figure 8 we show a circuit diagram of the General Electric Model HM-50 Frequency Modulation Receiver.

Checking the action briefly, the antenna transformer, L1, has a center tapped primary for use with a dipole antenna and balanced transmission line. The secondary, tuned to the mean carrier frequency, connects across the control grid circuit of the 6K8 converter tube. The oscillator coil, L2, is connected to the proper grid and plate elements of the 6K8 and tuned to a frequency which heterodynes the carrier to produce an i-f of 2100 kc or 2.1 mc.

The output circuit of the 6K8 is carried through the first i-f transformer L3 which drives the grid circuit of the 6SK7, first i-f tube. A second i-f stage, consisting of transformer L4 and the second i-f 6SK7 amplifier tube follows.

The third i-f transformer, L5, drives the grid circuit of the 6SJ7 Limiter tube, the circuit of which is similar to that shown in Figure 3. Its action, of course, is as previously explained.

Transformer L6 corresponds to the i-f transformer of Figure 5 and the tube marked "6H6 Detector" is the discriminator. The signal voltage appears across the two "100M" resistors and the greater portion of this signal is fed from the midpoint of the 100M - 220M voltage divider networks to Switch S2 and through the .005 mfd coupling condenser to the "2 megohm" volume control. In effect, the 100M resistor, operating in conjunction with the condensers controlled by switch S1, serve as a "De-emphasis" network. That is, if the f-m transmitter employs a pre-emphasis circuit which, in the modulator circuit, provides a greater amplitude of the high frequencies, then it is necessary to reduce the emphasis of the high audio frequencies in the receiver. Of course, the basic circuit arrangement here is that of the high frequency tone control.

With pre-emphasis at the transmitter, it is necessary to have de-emphasis at the receiver for the purpose of bringing the high frequencies down to the same proportion with respect to the low frequencies that exist at the studio microphone. The use of the de-emphasis network will reduce the high frequency noise picked up by the receiver antenna or from thermal agitation and "shot effect" to inaudibility.

The signals continue from the movable arm of the volume control through the "P-A" terminals and through another .005 microfarad coupling condenser to the grid of the 6SF5 a-f amplifier tube.

The plate circuit of the 6SF5 is resistance coupled to the grid circuit of the 6Y6G output tube which, in turn, is coupled to the speaker by transformer T1.

The power supply is conventional and consists of the usual type of power transformer with a 5Y3G full wave rectifier. The filter however, differs from the common type in that no iron core chokes are employed.

The rectifier filament connects directly to the primary of the output transformer with a 40 mfd condenser to ground. For the other plate circuits, the supply is through two resistors with a 20 mfd condenser to ground at the load end of each.

AUDIO AMPLIFIER

Switch S2 makes it possible to connect a phonograph pick-up across the grid, or input circuit of the first audio amplifier tube through the regular volume control.

The "P-A Terminals" make it possible to use the receiver as an f-m tuner and feed the audio signals into a p-a system or other audio amplifier. When the terminals are shorted, the incoming signal is fed to the grid circuit of the "6SF5 a-f Amp." to operate the audio amplifier and its speaker. The signal is also available between the p-a terminal connected to the volume control and ground.

Checking the values in the 6SF5 stage you will find a plate load of 220 M ohms, a grid load of 15 megohms and a cathode resistor of 82 ohms. As this is a high mu triode with a normal plate current of less than 1 ma, the voltage drop caused by plate current in the 82 ohm resistor will be negligible.

Therefore, we consider the tube as operating under conditions of "zero bias", an arrangement which has been found to provide high gain and low distortion with a minimum of parts. This method is particularly adapted to high mu triodes and in general consists of eliminating the cathode resistor while the value of the grid resistor is greatly increased.

For most purposes, we consider that, for Class A operation of an amplifier tube, the grid current is zero. That is not strictly true because, even with a negative bias, there is a small grid current which varies with the grid voltage.

By greatly increasing the usual value of the grid resistance, this small grid current will cause a voltage drop sufficient to properly bias the grid circuit. For example, in the circuit of Figure 8, a grid current of .1 microampere in the 15 megohm grid resistor will cause a drop of 1.5 volts and the normal rating of the 6SF5 is -2 volts on the grid. Therefore, the 82 ohm cathode resistor does not provide the grid bias voltage in the usual way but, tracing from the cathode, you will find a circuit through the 220 ohm resistor, bypassed with a .1 mfd condenser, and through the secondary of output transformer T1 to ground.

For this circuit, the output transformer supplies the voltage and thus inverse feedback is provided as part of the speaker voice coil voltage is fed back to the cathode of the first audio amplifier tube.

The current caused by that voltage, in passing through the 82 ohm resistor, produces sufficient voltage drop to bias the grid. Due to the relative value of the 220 ohm and 82 ohm resistors, slightly more than 25% of the voice coil voltage will be fed back to the cathode circuit.

The .1 mfd condenser, connected across the 220 ohm resistance acts as a sort of auxiliary tone control because, at higher frequencies, it becomes a partial short across the resistance. With a reduction of effective resistance, feed back voltage across the cathode resistance will be greater and thus the higher frequencies will be attenuated to a greater degree to cause an apparent bass boost.

It is interesting to note that this audio amplifier really has three tone controls. 1. The bass compensated volume control, 2. The switch type shunt capacity tone control and 3. Inverse feed back compensated for high frequency attenuation.

ALIGNMENT

As previously explained, the i-f amplifier must pass a 150 kc to 200 kc band, the exact width depending on the manufacturer's specifications. The i-f amplifier output is measured by means of a micro-ammeter connected in the limiter grid circuit or a vacuum tube voltmeter connected across the limiter grid bias resistor. 8.

Some manufacturers recommend a 300 kc frequency modulated oscillator, as a signal source of i-f amplifier adjustment, with an oscilloscope as the indicating instrument. The actual response curve of the amplifier can thus be seen and corrected by proper adjustment.

Other manufacturers suggest the use of a good signal generator of the usual Radio type, output readings to be taken at the intermediate frequency and also at points 75 kc to 100 kc above and below. Comparison of these three output readings indicates the shape and band width of the amplifier response.

For either method, the output indicator is connected in the grid circuit of the Limiter and the usual plan is to increase the signal input to a point at which no further increase of output is noted. This assures correct Limiter action and proper operation.

The adjustment of the Discriminator, or second detector input circuits is quite critical because, for best results, its output voltage must be symmetrical in respect to the intermediate frequency. Using a frequency modulated oscillator and oscilloscope, and referring to the diagram of Figure 5, the vertical plates of the scope are connected across the load resistors which correspond to R3 and R4. The Discriminator transformer trimmers are then adjusted to produce a curve like that of Figure 7, care being taken to have the cross over point in the proper position with an approximately straight line, as far as possible, on both sides of it.

To make the same adjustment, using an ordinary oscillator and micro-ammeter, the meter is connected across the load resistors but in such a position so as to be in series with a resistance such as R1 of Figure 5. When aligning with a vacuum tube voltmeter, it can be connected across the load resistors the same as the vertical plates of the oscilloscope. 9.

To obtain maximum output reading, the primary is tuned to the signal frequency but the secondary must be detuned because when it is resonant, the total output voltage is zero. 10.

The test oscillator is then set at 75 kc to 100 kc below the i-f and, as the polarity of the output voltage will be reversed, it will be necessary to reverse the test meter connections. For this particular job a meter scale with a center zero is convenient as it eliminates the need for reversing connections.

The output voltage should be checked again and a peak value obtained by a slight readjustment of the trimmers if necessary. After this has been done, the oscillator frequency should be tuned to the exact value of the i-f at which point the output should have decreased. The secondary trimmer is then carefully adjusted until the output is zero.

This is an extremely important adjustment and, if there appears to be more than one setting for zero output, the position of greatest sensitivity is the proper one.

The oscillator frequency should then be changed slowly to values above and below the i-f, one way causing a positive output and the other way a negative output. The primary trimmer adjustment can then be chec hed to make sure the output is of approximately the same value at equal frequencies above and below the i-f.

The alignment and tracking of the converter and oscillator stage is usually somewhat simpler as a low frequency oscillator padding condenser is seldom needed. It is usually sufficient to simply adjust the trimmer condensers for maximum output at the high frequency end of the tuning range.

ADVANTAGES OF F-M

While there have been many claims and counter claims in respect to f-m vs a-m, it seems to generally conceded that, for transmission at equal power levels, the f-m signals are received with much lower noise levels.

For amplitude modulation, the noise levels are in proportion to the band width but, for frequency modulation, the reverse is true. Checking back on the action of the limiter and second detector, you will remember that the amplitude of the signal is proportional to the frequency deviation while the noise or amplitude modulation, remains the same. Thus, the wider the band the better the signal to noise ratio.

Another advantage of frequency modulation is that of less interference between two stations transmitting on the same carrier frequency. In effect, therefore, although the f-m stations require a wider band, more of them can operate on the same carrier frequency without interference. This is due to the reduced interference and also because the high carrier frequencies, used for f-m Transmission, limit the service area of the Broadcast stations somewhat as compared to those operating on lower carrier frequencies.

TECHNICAL AND ECONOMIC PROBLEMS

From a technical standpoint, there has been a great deal of discussion as to the methods of comparing a-m and f-m systems. It is quite well known that certain forms of interference, troublesome in the present Broadcast band, are greatly reduced or disappear entirely at the high carrier frequencies used for f-m. However, f-m seems to have a distinct advantage in respect to "man made Static" which can cause trouble at most frequencies.

Two technical problems which must be solved are the band width which will allow good f-m reception with minimum noise and whether the public will be served better by allocating more frequencies for f-m, or by allowing more a-m stations to transmit on the ultra high frequencies.

From an economic standpoint, there is a wide difference of opinion as to whether or not the public will appreciate the reduced noise and higher fidelity f-m programs to the extent of buying new receivers. In this country, practically all Broadcast stations are supported by the sale of time to advertisers. The prices paid depend greatly on the estimated size of the listening audience and, unless assured of such an audience, the advertiser would not buy time of an f-m station.

Under this condition, the burden on the station would be heavy because, even though the public appreciated the advantages of f-m, they would not purchase receivers unless assured of good programs.

FUTURE POSSIBILITIES

With all of these conditions in mind, many predictions have been made regarding the future of Frequency Modulation. One quite plausible forecast is that the larger cities and other densely populated areas will be serviced by broad band, high frequency f-m stations while the more sparsely populated areas will be served, as now, with lower frequency a-m stations.

The wide band f-m system is sufficiently flexible to permit multiplex operation on the same channel. This would allow the transmission of two simultaneous programs such as one for sound and one for facsimile.

Frequency modulation has been called a "Revolution in Radio Broadcasting" and we have tried to indicate briefly, a few of the more important problems which it has brought up. The entire science of Radio is comparatively young, it is only natural that many improvements will have to be made. It is but a few years ago that there was ample space on the air for every active station and the amateurs were assigned all the frequency bands below 200 meters or above 1500 kc.

Today the entire Radio spectrum from 10 kc to 300,000 kc or 300 m-c has been definitely allocated for specific services and the present trend is toward higher and still higher frequencies because that appears to be the only direction in which additional space is available.

Frequency modulation seems to be well adapted for the higher frequency carriers and its demonstrated advantages seem to assure it quite an important place in the radio broadcast systems of the near future.

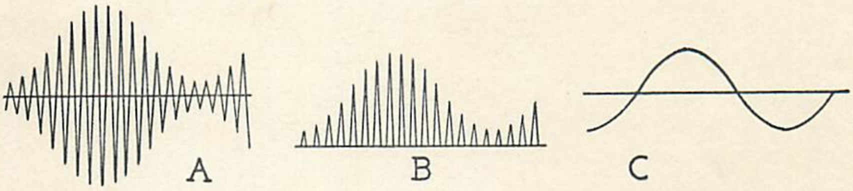


FIGURE 1

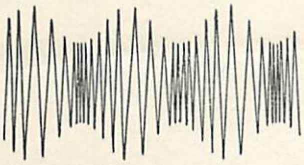


FIGURE 2

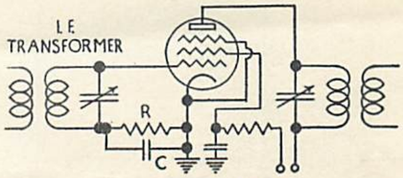


FIGURE 3

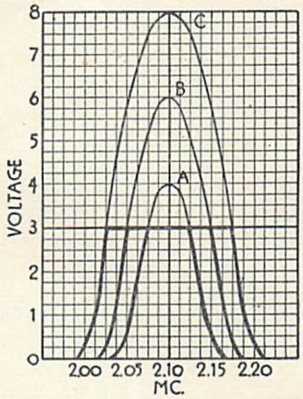


FIGURE 4

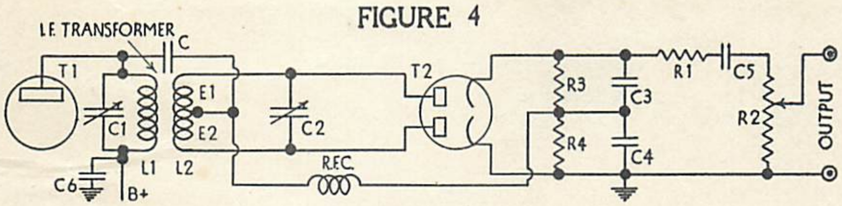
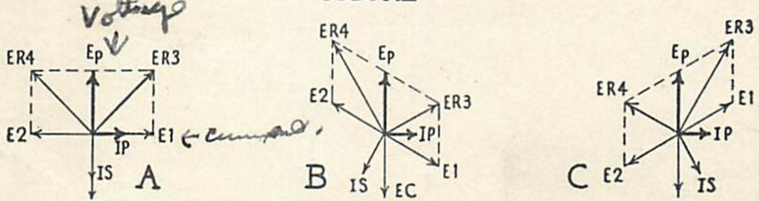


FIGURE 5



Voltage

← Current.

FIGURE 6

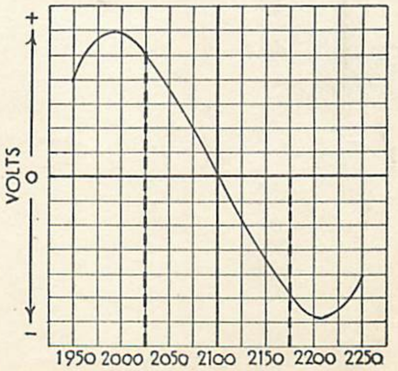


FIGURE 7

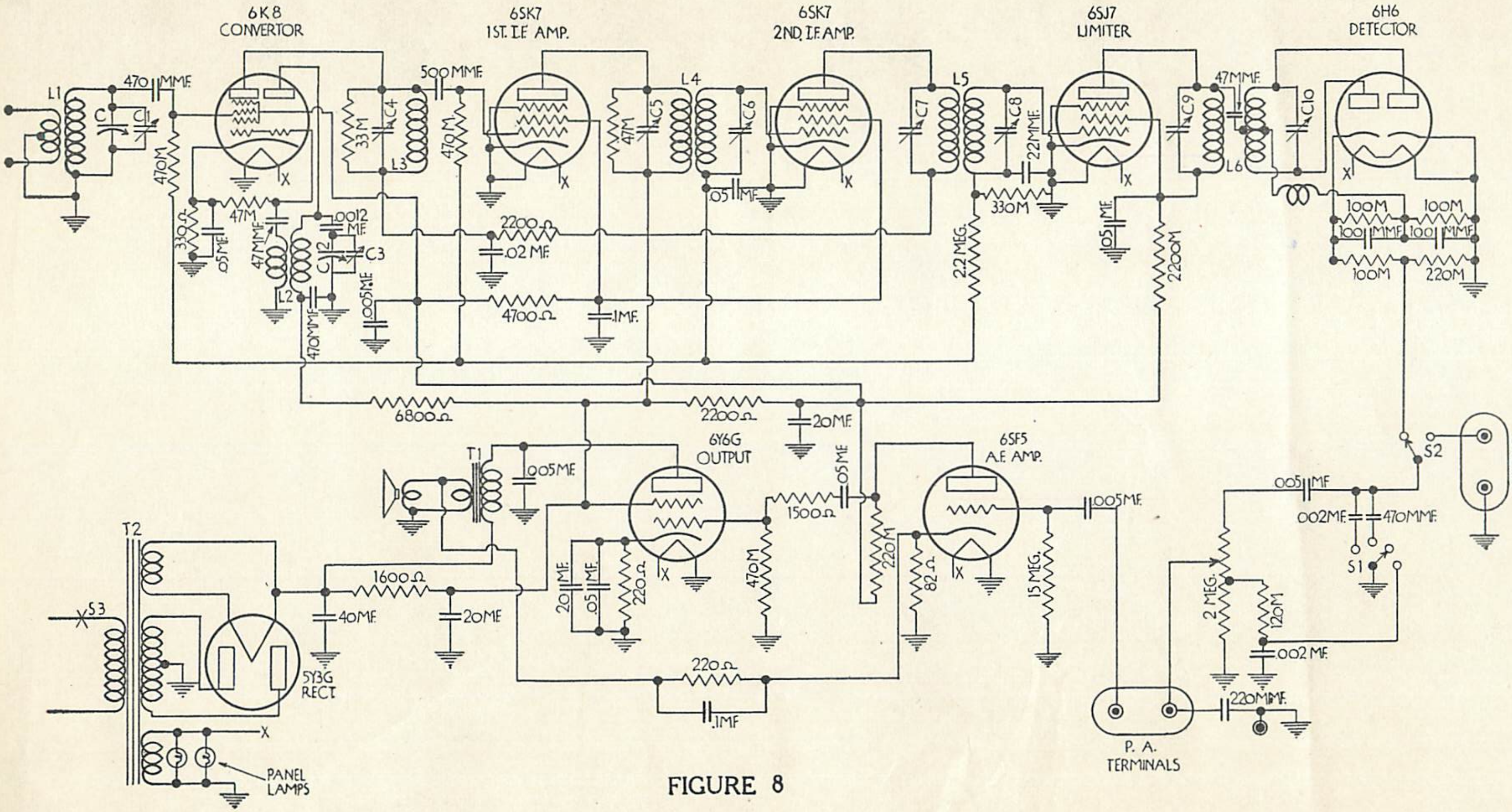

6K8
CONVERTOR
6SK7
1ST. I.F. AMP.
6SK7
2ND. I.F. AMP.
6SJ7
LIMITER
6H6
DETECTOR
L1
C
C1
470 MMF.
470M
330Ω
.05 MF.
47M
47 MMF.
.0012 MF.
C12
C3
L2
470 MMF.
.005 MF.
500 MMF.
33M
C4
L3
470M
2200Ω
.02 MF.
4700Ω
.1 MF.
47M
C5
L4
C6
.05 MF.
L5
C7
C8
22 MMF.
330M
2.2 MEG.
.05 MF.
2200M
C9
47 MMF.
L6
C10
X
100M
100M
100 MMF.
100 MMF.
100M
220M
6800Ω
2200Ω
20 MF.
T1
.005 MF.
6Y6G
OUTPUT
6SF5
A.F. AMP.
.05 MF.
1500Ω
220M
82Ω
15 MEG.
.005 MF.
470M
20 MF.
.05 MF.
220Ω
T2
S3
1600Ω
40 MF.
20 MF.
5Y3G
RECT.
220Ω
.1 MF.
PANEL
LAMPS
S2
PHONO.
.005 MF.
.002 MF.
470 MMF.
S1
2 MEG.
120M
.002 MF.
220 MMF.
P. A.
TERMINALS

FIGURE 8

QUESTIONS AND ANSWERS

1. Does the majority of the noise entering a radio receiver amplitude or frequency modulate the incoming carrier?
   It amplitude modulates the incoming carrier.

2. In an f-m receiver, what is the purpose of the limiter stage?
   Its purpose is to eliminate amplitude modulation of the carrier.

3. What is the pass-band of most i-f amplifiers used in f-m receivers?
   The pass-band is generally considered as being 150 to 200 kc.

4. In an f-m receiver, how is the wide pass-band of the i-f amplifier usually obtained?
   The wide pass-band is usually obtained by tightly coupling the windings of the i-f transformers and loading them with resistance.

5. What must be done to the frequency changes of the limiter output in order to produce audible signals?
   The frequency changes must be converted to voltage variations.

6. On what does the action of the circuit of Figure 5 depend?
   It depends on the phase relations caused by the changing i-f frequency.

7. Under what conditions is the current in L2-C2, Figure 5 in phase with the induced voltage?
   When the secondary, L2-C2, is tuned to resonance, its current will be in phase with the induced voltage.

8. Where is a microammeter connected to align the i-f transformers in an f-m receiver?
   The microammeter is connected in the limiter grid circuit.

9. Where is a vacuum tube voltmeter connected to align the discriminator transformer of an f-m receiver?
   The vacuum-tube voltmeter is connected across the load resistors of the discriminator tube.

10. Should the primary of the discriminator transformer be tuned for maximum or minimum deflection of the output indicator?
    It should be tuned for maximum deflection.